



ISSN (E): 2277-7695

ISSN (P): 2349-8242

NAAS Rating: 5.23

TPI 2022; 11(6): 42-51

© 2022 TPI

www.thepharmajournal.com

Received: 16-03-2022

Accepted: 23-05-2022

Vismaya Satheesh

Department of Food Technology and Nutrition, School of Agriculture, Lovely Professional University, Phagwara, Punjab, India

Jaspreet Kaur

Department of Food Technology and Nutrition, School of Agriculture, Lovely Professional University, Phagwara, Punjab, India

Sapna Jarial

Department of Agricultural Economics & Extension, School of Agriculture, Lovely Professional University, Phagwara, Punjab, India

Payel Ghosh

Department of Food Technology, Vignan's Foundation for Science, Technology and Research, Vadlamudi, Guntur, Andhra Pradesh, India

Kartik Sharma

International Center of Excellence in Seafood Science and Innovation (ICE-SSI), Faculty of Agro-Industry, Prince of Songkla University, Hat Yai, Songkla, Thailand

Manvi Patni

Department of Nutrition, B.D. Arya College, Jalandhar, Punjab, India

Jyoti Singh

Department of Food Technology and Nutrition, School of Agriculture, Lovely Professional University, Phagwara, Punjab, India

Vishesh Bhadariya

Department of Chemical and Petroleum Engineering, School of Chemical Engineering and Physical Sciences, Lovely Professional University, Phagwara, Punjab, India

Corresponding Author:**Jaspreet Kaur**

Department of Food Technology and Nutrition, School of Agriculture, Lovely Professional University, Phagwara, Punjab, India

Indian borage: A comprehensive review on the nutritional profile and diverse pharmacological significance

Vismaya Satheesh, Jaspreet Kaur, Sapna Jarial, Payel Ghosh, Kartik Sharma, Manvi Patni, Jyoti Singh and Vishesh Bhadariya

Abstract

Indian Borage (*Plectranthus amboinicus*) belonging to family *lamiaceae*, is the most widely available and cultivable medicinal plant. Country borage, Pathachur, Oregano, Spanish thyme, Oregano brujo (Puerto Rico), Mexican mint, and Mexican thyme are some of the other popular names for this plant. It is rich in various macro and micro nutrients such as carbohydrates, proteins, fats, fiber, flavanoids, phenols, zinc, calcium, ascorbic acid, ecosinoids and oleic acids. Owing to its rich nutritional value and phytochemical potential, it exhibits bioactive properties like anti-microbial, anti-bacterial, anti-fungal, anti-inflammatory, anti-diabetic, anti-anxiety, anti-neoplastic, anti-urolithiactic, anti-clotting, analgesic and anti-biofilm efficiency. Moreover, it aids in wound-healing, chest congestion, burns, whooping coughs, sinusitis, asthma, rheumatoid arthritis, myclonic jerks and maintains skin integrity. Phytochemical content of this plant has led the pathway for the production of Indian Borage oil, powder, perfume, syrup etc. The present review highlights the multifaceted aspects of Indian Borage, its geographical distribution, nutritional composition, pharmacological profile, health benefits, traditional utilization as well as commercialization. It will help to gain the attention of researchers and scientists in order to study the unexplored facts of this plant.

Keywords: *Plectranthus amboinicus* (Indian borage), nutritional composition, pharmacological value, health benefits, utilization

1. Introduction

Indian Borage is one of the most popular herbs which possess several health benefits. It is also known as *Coleus amboinicus* Lour, *Coleus aromaticus* Benth and *Plectranthus amboinicus* (Lour.) Spreng. In various parts of India, country borage has been familiar with different colloquial names viz 'Pathachur' in Hindi and Bengali (Chopra *et al.*, 1956, Kirtikar *et al.*, 1935, Sharma *et al.*, 1995, Kumar *et al.*, 2007) [38, 39]. Indian Borage is designated by different names across the globe like Cuban oregano, Spanish thyme, Oregano brujo (Puerto Rico), Mexican thyme, Mexican mint (Prakash *et al.*, 2012) [14]. It is an angiosperm, eudicots, and asteroids (Prakash *et al.*, 2012 & Anonymous, 2020) [14]. Lamiaceae family is branched with herbs, shrubs, and trees which unite 200 genera and 3200 species under it. Major highlight of these plants being their pharmaceutical and food utilization (Prasad *et al.*, 2020) [29]. *Plectranthus amboinicus* is seen in the tropical parts of the world hence it is a pantropical genus. It is enclosed with 300 species of sub shrubs or annual or perennial herbs (Wagner & Lorence, 2014) [56]. Previously, P.amboinicus was put under the genus *Coleus*, by Loureiro in 1790 but later it was shifted to the *Plectranthus* genus by Sprengel in 1825 (Anonymous, 2019). Though its origin is unknown yet but most researchers revealed that it is distributed and cultivated in India and Africa in almost all the tropical regions of both hemispheres whereas, P.amboinicus originated as a shrub in the United States (USDANRCS, 2014) [55]. *Plectranthus amboinicus* is quite drought resistant and can even grow in colder conditions (Staughton, 2020). It is a succulent perennial herb (Wagner & Lorence, 2014; Anonymous, 2019) [56] with leaves possessing fine tender hair providing a typical aroma which hold back its position all time (Prasad *et al.*, 2020) [29]. The plant is used to cure a wide range of health ailments such as malaria, inflammation, cough, chronic asthma, bronchitis, liver disorders, kidney stones and gallstones (Kaliappan & Viswanathan, 2008) [20]. The Lamiaceae family produces essential oils with insecticidal properties (Ebadollahi *et al.*, 2020) [4] due to the presence of two main phenolic monoterpenes, carvacrol and thymol, which have insecticidal properties (Singh *et al.*,

2002, Satongrod *et al.*, 2020) [8, 9]. *P. amboinicus* essential oil has insecticidal efficacy against a variety of insects, including the cowpea weevil (*Callosobruchus maculatus*), mosquito larvae (*Aedes aegypti* and *Anopheles gambiae*), red flour beetle (*Tribolium castaneum*), and termite (*Odontotermes obesus*). Contact and fumigant toxicity tests were used to determine the insecticidal activity of the essential oil from *P. amboinicus* against *S. calcitrans* and *T. megalops*, as well as histological and scanning electron microscopy evaluations of the essential oil's effects on these flies (SEM) (Lima *et al.*, 2011, Verma *et al.*, 2012, Singh *et al.*, 2014, Singh *et al.*, 2002) [10-13].

During infection - induced diarrhoea, the leaves of *P. amboinicus* are ingested with buttermilk, yoghurt, and other dairy products (Damanik *et al.*, 2006) [3]. In Indonesia, it is used as a traditional remedy in worm infection as well as to encourage lactation (Shubha and Bhatt, 2015) [14]. Owing to the increased consumer demand for natural and non-synthetic alternatives rather than chemical preservatives, researchers look into the extracts of various plant materials and essential oils because of their biological efficacy to delay or inhibit the growth of pathogenic or toxin producing microorganisms in food products (Gupta *et al.*, 2016). This review paper aims to provide a deep insight into the potential uses of Indian Borage, its nutritional profile, rich phytochemical profile and

traditional utilization. The further utilization of Indian Borage with respect to its different fragments are mentioned in this review.

2. Classification

Plectranthus is a paleotropical genus of about 300 annual or perennial herbs or subshrubs, many of which are succulent. Its name is originated from the Greek word 'plectron' which means "spur," and "anthos," which refers to spur shaped flowers (Stearn, 1992) [51]. Due to the lack of clear morphological standards, it is impossible to distinguish species within the genus *Pteris* alongwith in similar genera. Therefore, many taxonomic problems in species naming have led to the misalignment of the species particularly for *Coleus* (Lukhoba *et al.*, 2006) [24]. Many issues with taxonomic naming led to incorrect placement in species of closely related genera like *Englerastrum* *Coleus* and *Solenostemon* because of no comprehensive and precise knowledge of external features to distinguish between species of the genus *Plectranthus* (Morton, 1992) [27]. However, a method of classification has been proposed by which the medicinal plant variety can be distinguished by employing NIRS technique which helps in identifying a plant variety through the spectral signatures of leaves (Rajesh *et al.*, 2013) [53]. The botanical classification of Indian Borage has been presented in Figure 1.

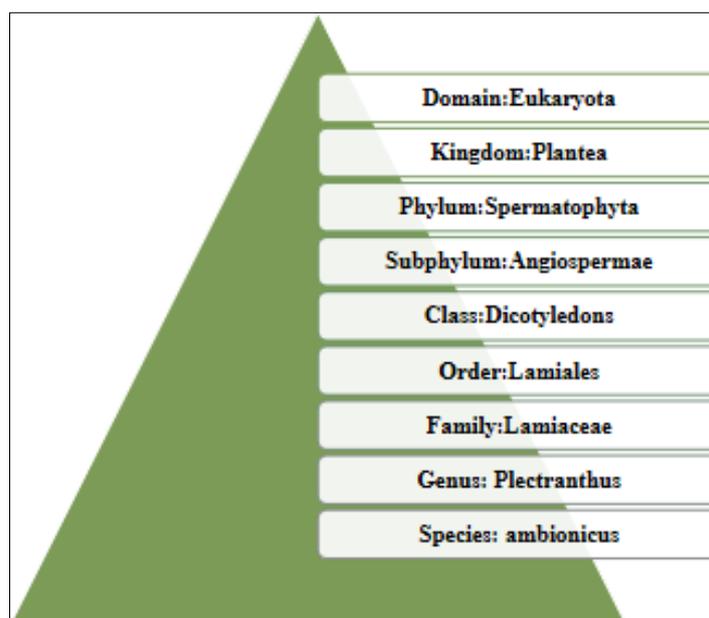


Fig 1: Botanical Classification of Indian Borage (Anonymous, 2019; Kumar *et al.*, 2020) [15]

Table 1: Colloquial names of Indian Borage

Origin	Colloquial names
Sanskrit	Parnayavini, Karpuravalli, Sugandhavalakam
Bengali	Paatharchur, Paterchur, Amarkuchi
English	Country Borage, Indian Borage, Indian Mint, French Thyme, Cuban Oregano, Mexican Mint, Soup Mint, Spanish Thyme
Gujarati	Ovvapaan
Hindi	Pattaajvaayana, Pattaajavayin, Patharchur, Amroda, Patharchur
Kanada	Karpurahalli, Penova, Doddapatre, Doddapatre Soppu
Malayalam	Kannikurkka, Panikkurukka, Navarayilla, Panikoorka
Oriya	Hemakedar, Amarpoi
Punjabi	Patharachur
Tamil	Karpuravalli
Telugu	Kapparillaku, Vamu-aku
Marathi	Panova, Pathachur
Spanish	Oregano

French	Oreille, ti baume
Cuba	Orégano, Orégano de Cartagena
Domainican Republic	Orégano de Espana, Orégano poleo, Oreille
Fiji	Rhaivoki & Sage
Germany	Jamaika thymian
Indonesia	Daun kutjing
Lesser Antilles	Ditengo, Gros Thyme, Soup Thyme, Thyme, Wild Thyme
Malaysia	Bangun Bangun
Niue	Pasiole
Philippines	Suganda, Toronjil de limón
Puerto Rico	Orégano brujo, Orégano de Espana
Samoa	Militini
Sweden	Kryddkarlbergare
Tonga	Kaloni, pasiole
Vietnam	Can day lá

Sources: Kirtikar *et al.* 1935; Chopra *et al.* 1956; Sharma *et al.* 1995; Anonymous, 2019 [38, 39]

3. Geographical distribution

P. amboinicus is a fast-growing plant that propagates through stem cuttings. The vegetative method of propagation is also seen because the plant seldom sets seed (Staples and Kristiansen, 1999) [54]. Organic rich soil, high humidity, and a neutral pH are optimum conditions for *P. amboinicus* to grow. Furthermore, this plant grows easily in indoors and thus is considered as a houseplant in Northern Europe. In India, it is widely grown in gardens. In partial shade, the plant thrives in either full sun or shade, but prefers a well-drained and stable soil. However, it is considered invasive in some areas, especially tropical islands, due to its ease of care and rapid growth (Roux *et al.*, 2003). It can be preferably found growing in rocky, loamy, or sandy soils. *P. amboinicus* is

found at low elevations in Mesoamerica, where it grows from 0 to 800 metres, and in Bolivia, it has been found at 0 to 500 metres (Roux, 2003). It is a plant that grows in a variety of climates, varying from warm temperate to tropical, with dry to wet winters. It thrives in a variety of environments, including forest or coastal areas, rocky hills, and low-elevation loamy or sandy flats (Humbert *et al.*, 1951) [44]. Deliberate human introduction for cultivation of *P. amboinicus* has spread to most tropical parts of the world (Pier, 2014) [43]. A complete detail of its geographical distribution is presented in Table 2. Studies have reported that due to its continued popularity as a culinary and medicinal herb, the possibility of introduction for this species is likely to remain high (Roux, 2003).

Table 2: Geographical Distribution of Indian Borage

S. No.	Country	Origin	References
1.	Angola	Native	Roux (2003);
2.	Antigua	Introduced	Lukhoba <i>et al.</i> (2006) [24];
3.	Barbados	Introduced	Govaerts (2014);
4.	Bangladesh	Introduced	USDA-ARS (2014) [55];
5.	Belize	Introduced	Missouri botanical garden (2014)
6.	Burundi	Native	PIER (2014) [43]; Anonymous (2019)
7.	Cambodia	Introduced	
8.	Comoros	Introduced	
9.	Eswatini	Native	
10.	Fiji	Introduced	
11.	Florida	Introduced	
12.	Gabon	Native	
13.	Jamaica	Introduced	
14.	Kenya	Native	
15.	Madagascar	Introduced	
16.	Maluku Islands	Introduced	
17.	Mexico	Introduced	
18.	Netherlands Antilles	Introduced	
19.	New South Wales	Introduced	
20.	Philippines	Introduced	
21.	Sri Lanka	Introduced	
22.	South Africa	Native	
23.	Taiwan	Introduced	
24.	Tanzania	Native	
25.	Thailand	Introduced	
26.	United States	Introduced	
27.	Vietnam	Introduced	

4. Nutritional composition

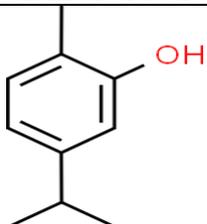
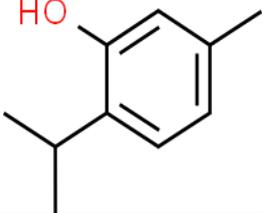
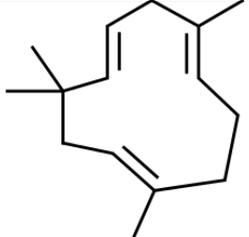
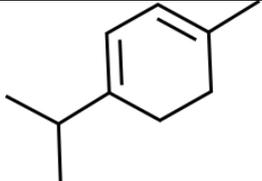
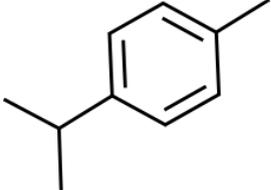
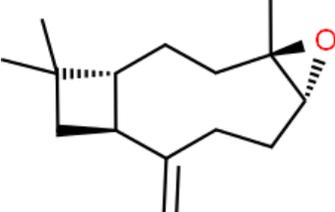
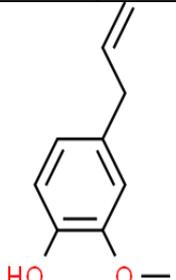
P. amboinicus is regarded as a potent supplement in the human diet owing to the high concentration of minerals *viz*

calcium and potassium (Lukhoba *et al.*, 2006) [24] and other compounds such as zeaxanthin, neoxanthin, leptin, violaxanthin and carotene. It is also good source of total

saturated and total unsaturated fatty acids which accounts for 15.1 - 16% and 83.4 - 84% (Tasets *et al.*, 2013). It is a nutrient - dense plant which contains macronutrients (carbohydrates, proteins, lipids, fibre) as well as micronutrients (such as vitamins A, B1, B2, B3, B5, B6, B9 and C) and minerals (Ca, Fe, Mg, P, K, Na, Zn, Cu, Mn, and

Se). *P. amboinicus* is a source of carvacrol that help in maximizing the taste and shelf life of food. Studies also show the presence of various biomolecules, indicating its potential application as functional food ingredient and nutraceutical emergence (Arumugam *et al.*, 2016)^[7].

Table 3: Percentage of chemical compounds present in essential oil of Indian Borage

Chemical Compounds	Chemical structure	Amount (%)	References
Carvacrol		28.65	Prakash <i>et al.</i> (2012)
Thymol		21.66	
α -humulene		9.67	
Undecanal		8.295	
Terpinene		7.76	
<i>p</i> -cymene		6.46	
Caryophylleneoxide		5.85	
Eugenol		4.40	

P. amboinicus also features a significant content of iron (3.3 mg). Iron is a crucial component of haemoglobin that aids red blood cells to hold oxygen throughout the body. The presence of a wide variety of bioactive compounds in plant extracts as well as in essential oil is credited with the biological properties. The complete detail of the various compounds along with their structure and amount is mentioned in Table 3. It contains phytochemicals *viz* 70 volatile and 30 nonvolatile including monoterpenoids, diterpenoids, triterpenoids, sesquiterpenoids, phenolics, flavonoids, and esters (Arumugam *et al.*, 2016) [7]. Essential oil derived from Indian borage is used as a botanical insecticide which due to the

presence of potential terpenoids such as carvacrol, p-cymene, terpinene-4-ol, and thymol which acts as complementary to conventional insecticide (Hamraoui, 1995). The mono terpene carvacrol possess wide range of insecticidal activity and fumigant activity against various agricultural products, stored products, and medical insect pests (Ahn *et al.*, 1998) [48]. γ -linolenic acid found in Indian borage is reported to reduce arthritis pain by promoting joint regeneration. The herb's high ascorbic acid content makes it a good immune system booster. Moreover, the carotenoids and vitamin A content helps to improve vision, reduce oxidative stress in the eyes and even prevent macular degeneration (Staughton, 2020).

Table 4: Nutrition Composition of raw Indian Borage per 100 gram

Nutritional components	Amount (per 100 g)	References
Proximate analysis		
Ash (g)	1.43	Staughton (2020)
Moisture (g)	93	
Energy (kcal)	211	
Carbohydrate (g)	3.05	Pereira <i>et al.</i> , (2011); Pilerood &Prakash (2014) [12]
Protein (g)	1.79	USDA (2019); Staughton (2020) [55]
Lipid (g)	0.69	
Fiber (g) Insoluble Fiber Soluble Fiber	45.38	
Minerals		
Calcium (mg)	93	Pereira <i>et al.</i> (2011); USDA (2019); Staughton (2020) [55]
Iron (mg)	3.3	
Magnesium (mg)	51.68	
Phosphorus (mg)	52.8	
Potassium (mg)	469.6	
Sodium (mg)	79.6	
Zinc (mg)	0.20	
Copper (mg)	0.13	
Manganese (mg)	0.34	
Selenium (mg)	0.89	
Vitamins		
Vitamin A (IU)	4200	Pereira <i>et al.</i> (2011); USDA (2019) [55]
Vitamin C (mg)	35.05	
Vitamin B1 (mg)	0.05	
Vitamin B2 (mg)	0.15	
Vitamin B3 (mg)	0.9	
Vitamin B5 (mg)	0.04	
Vitamin B6 (mg)	0.08	
Vitamin B9 (ug)	13.49	
Other compounds		
Phenols	19.62±0.83% (wet basis)	Hullatt & Bhattacharjee (2011) [49]
Flavonoids	4.21±0.39% (wet basis)	
Alkaloids	4.3±0.74% (wet basis)	
Saponins	2.09±0.33% (wet basis)	

5. Pharmacological properties

Owing to the presence of several biological compounds, *P.ambionicus* exhibits different pharmacological activities including anti-microbial, anti-inflammatory, anti-tumor, wound cure, anti-epileptic, anti-larvicidal, antioxidant and analgesic property (Kumar *et al.*, 2020) [15]. It is used for the treatment of illnesses such as cold, asthma, constipation, headache, cough, diarrhea, and skin conditions. It has been found to be effective against respiratory, cardiovascular, oral, skin, digestive and urinary diseases (Arumugam *et al.*, 2016) [7]. The diseases like cephalgia, otalgia, anorexia, dyspepsia bloating, colic, diarrhea, cholera, gums, seizures, asthma, cough, chronic bronchitis, kidney calculi, vesicle calculi, hiccough, strangury, hepatopathy, fever, and malaria are treated using this herb. In Indian, Ayurvedic practitioners have used the *Coleus* varieties in chronic cough and asthma

including calculus, gonorrhoea, heart disease, fever, piles and dyspepsia (Koti *et al.*, 2011). *Coleus aromaticus* ethanolic extract is stated to have anti-carcinogenic potential. (Prasad *et al.*, 2002) [8]. Furthermore, *Plectranthus* species are used for heart disease, convulsions, spasmodic pain, and painful urination (Govindarajan *et al.*, 2015). *P. amboinicus* leaves contains the anti-inflammatory and anti-tumor properties (Gurgel *et al.*, 2009) [2]. An appreciable DPPH radical scavenging activity showed by ethyl acetate extract of leaves indicated the highest polyphenolic content (Bhatt *et al.*, 2012). It has been revealed that the leaf extract of *P.ambionicus* exhibits good antioxidant potential and showed significant superoxide scavenging ability, nitric oxide scavenging, and also ferrous ion chelating ability (Kumaran and Karunakaran, 2016). *P. amboinicus* are effective in the treatment of rheumatoid arthritis, which explains its anti-

rheumatic activity (Chang, 2007). Indian Borage's essential oil act against *A. ochraceus* contains carvacrol hence, exhibits efficient antifungal aspect (Bhatt & Negi, 2012). Indian Borage's leaf extracts have good anti-bacterial activity in different food systems as they reduce the counts of artificially inoculated bacteria from food models such as papaya, cabbage and natural microflora in chicken meat (Duptha *et al.*, 2016). This herb is used in the treatment of ulcers in some countries. *P. aromaticus* has the ability to reduce blood glucose levels, thereby used as an anti-diabetic agent (Kumar *et al.*, 2020) [15]. Studies provides evidence for folk uses of *Plectranthus amboinicus* (Lour.) and Spreng. in relieving pain and inflammation (Chiu *et al.*, 2015). Studies have revealed that the ethanolic extract of *P. amboinicus* demonstrated anti-cancer activity by inducing apoptosis in human lung cancer. Due to the presence of triterpenoids, Indian Borage functions as anti-inflammatory agent that minimize redness and swelling, as well as itchiness and inflammation, in any of the insect bites and stings, eczema and psoriasis (Aziz *et al.*, 2003). Being a diuretic, it helps in getting rid of toxic constitutes from the human body and thus helps to maintain urinary tract function (Duptha *et al.*, 2016). *Plectranthus amboinicus* (Lour) has also shown promising effect as a chemotherapeutic agent for colon cancer and further is used in colon cancer prevention. Ethanolic extract of *P. amboinicus*

has good anti-cancer potential (Rai *et al.*, 2016) [40]. The ethanolic extract's nano particles of *P. amboinicus* have an anti-proliferative effect on T47D breast cancer cells by inducing apoptosis (Hasibuan *et al.*, 2019). In addition, the stem of Indian Borage plant has high antioxidants and is capable of scavenging free radicals as well as shown to suppress cancer cell proliferation (Duptha *et al.*, 2016). Gallic acid, quercetin, rutin, and coumaric acid were some of the vital bioactive compounds found in quite significant levels in the crude extract of *P. amboinicus* stem. The primary chemicals found in the stem and aqueous extracts of Indian borage leaves are rosmarinic acid and caffeic acid. Rosmarinic acid is a caffeic acid ester with various biological actions well recognised for an antiproliferative effect on murine mesangial cells by suppression of platelet-derived growth factor (PDGF) and tumour necrosis factor (TNF). Gallic acid has been demonstrated to decrease cancer cell proliferation, and quercetin and its equivalents have been found to be anticancer. Quercetin and its glucosides, such as rutin, have potent antiplatelet, anticancer, and antibacterial properties. The existence of these biomolecules laid a position for *P. amboinicus* to be used as a potent functional food ingredients and nutraceuticals (Makino *et al.*, 2000, Tomas *et al.*, 2000, Joshi *et al.*, 2011) [16, 17, 18].

Table 5: Pharmacological activity of Indian Borage

Plant Part Used	Pharmacological Activity	References
Leaf essential oil	Anti-fungal activity, Anti-viral activity	Duptha <i>et al.</i> (2016); Rai <i>et al.</i> (2016) [40]; USDA (2019) [55]; Staughton (2020)
Leaf extract	Anti-bacterial activity, Lactogenic properties, Skin allergy Anti-viral activity, Anti-cancer & Activity against respiratory diseases	
Aerial part	Anti-inflammatory activity	
Root aqueous extract	Cardiovascular disorder, Antioxidant & Anti-epileptic activity	
Leaf paste	Burns	
Stem	Analgesic activity	

5.1 Anti-bacterial activity

The un-sterilized leaf extract of *P. amboinicus* shows anti-bacterial activity against *E. coli*, *S. aureus*, *P. mirabilis* and *K. pneumonia* which cause infected foot in diabetic patients. *P. amboinicus* leaves inhibits the growth of pathogens like *E. coli* and *Salmonella typhimurium* (Muniandy *et al.*, 2014) [28]. The ethanol extract of *P. amboinicus* has been demonstrated to exhibit anti-bacterial properties against both gram-positive and gram-negative bacteria (Chandrappa *et al.*, 2008). The hydroalcoholic extract (HAE) of the leaves demonstrated anti-bacterial action against MRSA (methicillin-resistant *Staphylococcus aureus*) (Gurgel *et al.*, 2009) [2]. The leaf extracts of *P. amboinicus* were screened against *Bacillus cereus*, *Staphylococcus aureus*, *Escherichia coli*, and *Yersinia enterocolitica*. (Negi *et al.*, 1999) [31]. *P. amboinicus* speeds up the healing process hence inhibit long-term inflammation which can delay the wound healing. This medicinal plant is used to treat bacterial infections caused by bacteria it shows potent anti-bacterial activity against the microbes which are found in sputum and lungs of humans. Amikacin is a medication, developed from the leaf extract of *P. amboinicus*, is used to treat various bacterial infections. It is also utilized to create zinc oxide nano particles for regulation in the growth of MRSA biofilms (Yuthistran *et al.*, 2015 & Kumar *et al.*, 2015) [21]. *P. amboinicus* possess anti-microbial compounds such as limonene, linalool, myrcene, thymol and cubebene (Lukhoba *et al.*, 2006) [24]. *Plectranthus amboinicus* (Lour.)

Spreng leaves have anti-bacterial activity against *Staphylococcus aureus* and *Streptococcus mutans* bacteria and can be compounded into a mouthwash (Nazliniawaty *et al.*, 2019) [30].

5.2 Anti-fungal activity

Indian Borage Oil has the potential use in botanical fungi toxicant against fungal attack in stored food commodities (Murthy *et al.*, 2009). *Serratiamarcensens*, *Pseudomonas aeruginosa*, *Penicillium spp*, *Aspergillus niger*, *Aspergillus flavus* (Ajitha *et al.*, 2014). *Proteus vulgaris*, methicillin resistant *S. aureus* (MRSA), *Candida albicans*, and *Candida tropicalis* were screened against its essential oil. Both microorganisms were found susceptible against *P. amboinicus* essential oil. Although, *P. amboinicus* essential oil has an inhibitory effect against *E. coli* and *S. aureus* (Manjamalai, 2012) [26] because of the presence of major mono terpenoid compounds, carvacrol, and camphor (Sabrina *et al.*, 2014), but *P. amboinicus* is not effective against *Candida albicans*, a fungal yeast (Sivaranjani *et al.*, 2019).

5.3 Anti-inflammatory activity

P. amboinicus extract may be an active, natural, and non-toxic that cures endotoxemia - induced inflammation and toxicity (Akinbo *et al.*, 2016) [1]. In experimental studies performed on mice, treatment with *P. amboinicus* leaf methanolic extracts had shown moderate to strong anti-inflammatory activity.

Moreover, an improvement in immunoglobulin and lysozyme levels was substantially seen in rats treated with *P. amboinicus* ethanolic leaf extract (Silitonga *et al.*, 2016) [37]. In addition to this, it has also been reported that *P. amboinicus* have blocked the acetic acid and formalin - induced pain, as well as carcinogen induced inflammation (Chiu *et al.*, 2012) [42].

6. Health benefits

Plant-based medications are now widely used in many public health practices around the world because they are safe and cost-effective, as well as they effectively combat a variety of dangerous diseases while also assisting in the maintenance of good health (Swamy *et al.*, 2011). Herbal preparations have been widely employed in Unani, Ayurveda, Sidda, folk medicine, as well as other traditional medical systems (Swamy *et al.*, 2015). *P. amboinicus* essential oil also prevents the development of the dandruff causing fungus *Malassezia furfur*, was tested using the agar diffusion method and compared to a Ketoconazole based shampoo as a control (Kumar *et al.*, 2012 & Manjamalai, 2012) [26]. Caries and periodontal disease trouble population. In Ayurvedic medicine, renal vesical calculi, cough, chronic asthma, hiccough, bronchitis, anthelmintic, colic pains, and convulsions have all been treated with the leaves of this herb.

It's widely grown and naturalized in the tropics, where it is used as common medicine, seasoning and ornamental herb (Devi *et al.*, 2008). Indian Borage is used with mouthwash to prevent bacterial growth in the oral cavity due to the presence of carvacrol (Santos *et al.*, 2015) [34]. Also, *P. amboinicus* is used in traditional Indonesian foods e.g. in soups to induce lactation during the first month or so after childbirth. In North Sumatra, particularly among the Batak tribe, the leaves are commonly consumed by new mothers. The high content of nutrients in the leaves of this herb, especially iron and carotene, is thought to increase breast milk production. The consumption of leaves improves the number of minerals in milk, such as iron, potassium, zinc, and magnesium, thus increasing the weight and health of infants (Silitonga *et al.*, 2015) [37]. *P. amboinicus* enhances platelet function which helps to prevent cardiovascular diseases (Bhatt *et al.*, 2013) [32]. *P. amboinicus* activity against rheumatoid arthritis is based on the different mechanisms from non-steroidal anti-inflammatory drugs. *P. amboinicus* can enhance the healing process and reduce the use of anti-inflammatory non-alcoholics, thus producing minimal side effects. Indian Borage is a sudorific, which means it induces sweating, which aids in the removal of contaminants from the skin and speeds up the healing process (Chiu *et al.*, 2009) [42].

Table 6: Health Benefits of Indian Borage

Property	Bioactive compounds	Effects	Way of using	References
Digestive stimulant	Phenol compounds: -Rosmarinic acid -Caffeic acid	Indian Borage leaves are primarily used to soothe upset stomach by calming inflammations of intestine and by maintaining the digestion to alleviate bowel syndromes. It helps to treat diarrhoea by speeding up the microbial gut balance during infection	By brewing the tea of borage leaves.	Yoganarasimha (2000); Haldi and Bremer (2001); Parika and Cooke (2003); Lukhoba <i>et al.</i> (2006) [24]
Wound Healer	Zinc	Due to the presence of zinc, borage leaves shows potential antimicrobial effects and act as strong immune stimulant that promotes the clean up process of microorganisms that declines the healing process and thereby sustains the pathway for normal development	Paste form leaf extract	Sreedharan <i>et al.</i> (2010); Krithi <i>et al.</i> (2015)
Anti-dermal	Omega 6 fatty acid - γ -linolenic acid	Borage oil is loaded v with γ -linolenic acid which plays a vital role in the rejuvenation of skin hence used to treat atopic dermatitis and psoriasis. γ -linolenic acid is responsible for reducing the swelling and redness during bee stings and bug bites by relieving the irritation. by enhancing joint regeneration thus reduces the stress on bones and joints. It also reduces the production of cytokines (potent contributor for the rheumatoid arthritis) and provides protection to the joints.	Borage leaf extract is use to rub over the affected part of skin.	Vere <i>et al.</i> (1993); Radav <i>et al.</i> (2011); Arumugan <i>et al.</i> (2016)
Cures respiratory tract problems	Rosmarinic acid Caffeic acid Rutin Gallic acid.	Borage is very useful treatment protocol of sore throat, stuffy nose, chest congestion, whooping cough, sinusitis and asthma by acting as powerful expectorant which removes the phlegm and mucus from the respiratory tract.	By consuming borage leaf extract with honey on daily basis.	Neuwinger (2000); Voganarsimha (2000); Canotvaheato (2004); Bhatt and Negi (2012)
Immune Stimulant	Vitamin C Phenol compounds: -Rosmarinic acid -Caffeic acid	High concentration of vitamin C (a potent antioxidant) makes Indian Borage a potent immunity booster. It prevents the bacteria, pathogens or any foreign bodies from entering into the body and multiplies by phagocytosis.		Sakong <i>et al.</i> (2011)
Promotes eye health	Vitamin A	The presence of Vitamin -A and Carotenoids makes borage to play vital role in improving vision, reducing the oxidative stress to eye and protects from macular degeneration.	Water boiled with borage leaves is used to wash eyes.	
Anti-depressant	Coumaric acid Rutin Gallic acid Caffeic acid	These bioactive compounds upholds a slight sedative effect and balances up the levels of serotonin and dopamine when the body experiences chronic stress myclonic jerks or any mental trauma. Hence promotes peace of mind and sound sleep.	Borage leaves are slightly heated over the flame and it is rubbed between the palms and the person is allowed to smell it.	Tiwari <i>et al.</i> (2012)

Diuretic	Vitamin B complexes Potassium Vitamin E Vitamin C Zinc	Owing to the presence of vital detoxifying nutrients, borage helps to clear out the toxins from body by promoting urination. It clears out the excessive fats, salts and water from body which helps to maintain the electrolyte balance hence keeps the lymphatic system well functional.	By drinking water boiled with borage leaves.	Patel <i>et al.</i> (2010)
Anti-pyrogenic activity	Caffeic acid Rosmarinic acid.	Indian Borage act as sudofiric agent during fever as it motivates perspiration in the body which helps to lower down body temperature and clears out toxins from the body, hence helps in speedy recovery.	By drinking its juice with honey or rock sugar (1-2 teaspoon) twice a day during fever.	Arjunan <i>et al.</i> (2011); Arumungan <i>et al.</i> (2016); Kumar <i>et al.</i> (2020) ^[15]
Anti-biofilm	Caffeic acid Rosmarinic acid.	It inhibits the formation of biofilm by the depressing the growth of <i>S.pyrogens</i> which cause pyrrngitis.		
Analgesic activity	Rosmarinic acid. Flavonoids: - Triterpenoids	It inhibits the nitric oxide synthase (i Nos) and nuclear factor kappa B which regulates cyclooxygenase2 which reduces the cramps and inflammation	Indian Borage essential oil can be applied on the affected area.	Neuwinger (2000); Yoganarasimhan (2000); Chifundera (2001)
Antiurolithiatic activity	Moisture Rosmarinic acid Vitamin C / Ascorbic acid	Reduce calcium oxalate accumulation in the urinary bladder and kidney by disrupting its structure, which causes fragmentation and creates a channel for simple excretion through urine.	Indian Borage juice is administrated by diluting it with water twice a day.	Morton (1992); Yoganarasimhan (2000) Kumar and Karunakaran (2006) ^[27]
Anti-oxidant activity	Carvacrol Thymol	Higher capacity for superoxide scavenging, nitric oxide scavenging, and ferrous ion chelation. As a result, alleviate the pressure caused by cell line in induced lung cancer.		

7. Traditional and Modern Utilization

P. amboinicus has wide applications in food industry where it is compulsory used as a substitute for oregano. The probiotic bacteria (*L. plantarum*) uses the phytoconstituents of the leaves by producing essential metabolic enzymes posing prebiotic effect on Indian Borage leaves. In addition to this, it serves as a uterine cleanser (Damanik, 2009). It has been well documented that the Indian Borage was used traditionally to settle upset stomachs and relieve irritable bowel syndrome (IBS) by regulating digestion and soothing stomach inflammation. Internally as a carminative and anti-asthma, and externally as an insect repellent, the herb is also used as a folk remedy for burns and bites. Coughs are treated with an infusion or syrup made from the aromatic leaves of Indian Borage. In India the paste of leaves are applied on eyes to treat conjunctivitis. Chapped lips, cracks at the corners of the mouth and snake bites are treated with leaf juice (Vere *et al.*, 1993, Radav *et al.*, 2011, Arumugan *et al.*, 2016). In animal feeding, Indian Borage is used as a fodder (Lukhoba *et al.*, 2006)^[24]. *P. amboinicus* is also used for spiritual and religious reasons (Arumughan *et al.*, 2013). In Brazil, it is used to treat skin ulcers caused by *Leishmania braziliensis*. In Taiwan, the folk herb *Plectranthus amboinicus* (*P. amboinicus*) is used to treat inflammatory diseases (Chang *et al.*, 2007). After washing, scented leaves of *P. amboinicus* are rubbed onto the hair and body to get rid off the body odour with a soothing fragrance. Moreover, the oils from this plant are used in aromatherapy in many health and wellness spas all around the world (Arumughan *et al.*, 2013). They are more widely used to season dishes with tomato sauces and as a flavoring in recipes that call for mixed herbs or oregano. In addition to this, the leaves are eaten raw with bread and butter in India or added to fritters. When chewed raw, the tender and soft leaves are crunchy and have an astringent flavour. The dried leaves can be used to make marinades and stuffing's. The leaves can be chopped and shaped into flour balls, which can then be fried in oil (Fern, 2014). Due to the fragrant aroma of its leaves, it is used in cooking and flavouring beer wine and meat dishes made from beef, lamb, chicken (Montor *et al.*, 1999, Kumar *et al.*, 2020)^[15]. This herb is used with some seasonings after drying mostly in the West Indies; in

Cuba, it is served with black beans and salsa; and in Japan, the plant's leaves are cooked and prepared like spinach (Kumar *et al.*, 2012). In Tonga and Martinique, the leaves are also used for the cleaning of textiles and to spray them (Lukhoba *et al.*, 2006)^[24].

8. Conclusion

In Indian medicine system, the *Plectranthus amboinicus*, holds a promising importance. The plant is widespread and cultivated all over the world. From leaves to roots every part of this plant holds great medicinal value. Leaves of this herb is used to treat various health issues such as; hepatopathy, renal calculi, cough, asthma recurrent, hiccough, bronchitis, fever, sore throats, mumps and mosquito bites. Indian Borage has historically been used to alleviate gastrointestinal upset and irritable bowel syndrome by controlling digestion. Indian Borage leaves tea is beneficial to human well-being. Moreover, it holds numerous phytochemicals and nutrients there by attracting food market and industries. As a result, *P. amboinicus* seems to have a bright future in the pharmaceutical and nutraceutical field, where organic, cost-effective, and nontoxic bioactive compounds are in high demand. But, more research is needed to isolate, identify, interpret, and authenticate the efficiency of bioactive components in *P. amboinicus*. Thus, *Plectranthus amboinicus* which has enormous usage and is easily available in almost every other house needs to be further exploited for its beneficial effects.

9. References

1. Akinbo DB, Onyeaghala AA, Emomidue JO, Ogbhemhe SO, Okpoli HC. Phytochemical and anti-inflammatory activities of aqueous leaf extract of Indian borage (oregano) on rats induced with inflammation. *Cancer Biomarkers*, 2018;22(2):257-265.
2. Gurgel APA, da Silva D, Grangeiro JG, Oliveira ARS, Lima DC, da Silva CM, AC Souza IA. *In vivo* study of the anti-inflammatory and antitumor activities of leaves from *Plectranthus amboinicus* (Lour.) Spreng (Lamiaceae). *Journal of Ethnopharmacology*. 2009;125(2):361-363.

3. Damanik R, Wahlqvist ML, Wattanapenpaiboon N. Lactagogue effects of Torbangun, a Batakese traditional cuisine. *Asia Pacific journal of clinical nutrition*, 2006, 15(2).
4. Ebadollahi A, Ziaee M, Palla F. Essential oils extracted from different species of the Lamiaceae plant family as prospective bioagents against several detrimental pests. *Molecules*. 2020;25:1556
5. Laila F, Fardiaz D, Yuliana ND, Damanik MRM, Nur Annisa Dewi F. Methanol extract of *Coleus amboinicus* (Lour) exhibited antiproliferative activity and induced programmed cell death in colon cancer cell WiDr. *International Journal of Food Science*, 2020.
6. Tanwar B, Goyal A, Kumar V, Rasane P, Sihag MK. Borage (*Borago officinalis*) Seed. In *Oilseeds: Health Attributes and Food Applications*. Springer, Singapore. 2021, 351-371.
7. Arumugam G, Swamy MK, Sinniah UR. *Plectranthus amboinicus* (Lour.) Spreng: botanical, phytochemical, pharmacological and nutritional significance. *Molecules*. 2016;21(4):369.
8. Singh G, Singh OP, Prasad YR, Lamposona MP, Catalan C. Studies on essential oils. Part 33. chemical and insecticidal investigations on leaf oil of *Coleus amboinicus* (Lour). *Flavour. Frag. J.* 2002;17:440-442.
9. Satongrod B, Wanna, R. Chemical composition and bioactivity of essential oil from Indian borage (*Plectranthus amboinicus* (Lour.) Spreng) against *Callosobruchus maculatus* (F.). *Int. J Agric. Technol.* 2020;16:1243–1256.
10. Lima MA, Oliveira FFM, Gomes GA, Lavor PL, Santiago GM, Nagao-Dias AT. Evaluation of larvicidal activity of the essential oils of plants species from Brazil against *Aedes aegypti* (Diptera: Culicidae). *Afr. J. Biotechnol.* 2011;10:11716–11720.
11. Verma RS, Padalia RC, Chauhan A. Essential oil composition of *Coleus aromaticus* Benth. from Uttarakhand. *J Essent. Oil Bear. Plant.* 2012;15:174-179.
12. Singh JP, Prakash B, Dubey NK. Insecticidal activity of *Ageratum conyzoides* L., *Coleus aromaticus* Benth. and *Hyptis suaveolens* (L.) Poit essential oils as fumigant against storage grain insect *Tribolium castaneum* Herbst. *J. Food Sci. Technol.* 2014;51:2210–2215.
13. Singh M, Lal K, Singh SB, Singh M. Effect of *Calotropis* (*Calotropis procera*) extract on infestation of termite (*Odontotermes obesus*) in sugarcane hybrid. *Indian J. Agric. Sci.* 2002;72:439–441.
14. Shubha JR, Bhatt P. *Plectranthus amboinicus* leaves stimulate growth of probiotic *L.plantarum*: Evidence for ethnobotanical use in diarrhea. *Journal of Ethnopharmacology*. 2015;166:220-227.
15. Punet Kumar S, Kumar N. *Plectranthus amboinicus*: a review on its pharmacological and pharmacognostical studies. *American Journal of Physiology*. 2020;10(2):55-62.
16. Makino T, Ono T, Muso E, Yoshida H, Honda G, Sasayama S, Inhibitory effects of rosmarinic acid on the proliferation of cultured murine mesangial cells, *Nephrology Dialysis Transplantation*. 2000;15(8):1140–1145,.
17. Tomas-Barberan FA, Clifford MN. Dietary hydroxybenzoic acid derivatives nature, occurrence and dietary burden, *Journal of the Science of Food and Agriculture*. 2000;80(7):1024-1032.
18. Joshi UJ, Gadge AS, Mello PD, Sinha R, Srivastava S, Govil G. Anti-inflammatory, antioxidant and anticancer activity of quercetin and its analogues, *International Journal of Pharmaceutical and Biomedical Research*. 2011;2(4):1756-1766.
19. Rattanachaikunsopon P, Phumkhachorn P. Contents and antibacterial activity of flavonoids extracted from leaves of *Psidium guajava*, *Journal of Medicinal Plant Research*, 2010;4(5):393-396.
20. .Kaliappan ND, Viswanathan PK. Pharmacognostical studies on the leaves of *Plectranthus amboinicus* (Lour) Spreng. *International Journal of Green Pharmacy*. 2008;380(IJGP):2(3).
21. Yuthistran R, Balakrishnan C, Buddhan R. Antibiotic effect of leaf extract from *Plectranthus amboinicus* (lour) spreng in asthma. *International Journal of Advance Research and Innovation*. 2015;3(2):430-432.
22. Khare RS, Banerjee S, Kundu K. *Coleus aromaticus* Benth-A nutritive medicinal plant of potential therapeutic value. *International Journal of Pharma and Bio Sciences*. 2011;2(3):488-500.
23. Pokharen N, Dahal S, Anuradha M. Phytochemical and antimicrobial studies of leaf extract of *Euphorbia neriifolia*. *Journal of Medicinal Plants Research*. 2011;5(24):5785-5788.
24. Likhoba CW, Simmonds MS, Paton AJ. *Plectranthus*: A review of ethnobotanical uses. *Journal of Ethnopharmacology*. 2006;103(1):1-24.
25. Swamy MK, Arumugam G, Kaur R, Ghasemzadeh A, Yusoff MM, Sinniah UR. GC-MS based metabolite profiling, antioxidant and antimicrobial properties of different solvent extracts of Malaysian *Plectranthus amboinicus* leaves. *Evidence-Based Complementary and Alternative Medicine*, 2017.
26. Manjamalai A, Grace VB. The chemotherapeutic effect of essential oil of *Plectranthus amboinicus* (Lour) on lung metastasis developed by B16F-10 cell line in C57BL/6 mice. *Cancer investigation*. 2013;31(1):74-82.
27. Morton JF. Country borage (*Coleus amboinicus* Lour.): A potent flavoring and medicinal plant. *Journal of Herbs, Spices & Medicinal Plants*. 1992;1(1-2):77-90.
28. Muniandy K, Hassan Z, Isa MHM. The action of *Coleus aromaticus* as a potential wound healing agent in experimentally induced diabetic mice. *PERINTIS e Journal*, 2014, 4(1).
29. Prasad N, Basalingappa KM, Gopenath TS, Razvi SM, Murugesan K, Ashok G. Nutritional Significance Of Indian Borage (*Plectranthus amboinicus*): A Review. *Plant Archives*. 2020;20(2):3727-3730.
30. Nazliniwaty Nazliniwaty LL. Formulation and antibacterial activity of *Plectranthus amboinicus* (Lour.) spreng leaves ethanolic extract as herbal mouthwash against halitosis caused bacteria. *Open access Macedonian journal of medical sciences*. 2019;7(22):3900.
31. Negi PS, Jayaprakasha GK, Jagan Mohan Rao L, Sakariah KK. Antibacterial activity of turmeric oil: a byproduct from curcumin manufacture. *Journal of agricultural and food chemistry*. 1999;47(10):4297-4300.
32. Bhatt P, Joseph GS, Negi PS, Varadaraj MC. Chemical composition and nutraceutical potential of Indian borage (*Plectranthus amboinicus*) stem extract. *Journal of*

- Chemistry, 2013.
33. Wanna R, Krasaetep J. Chemical composition and insecticidal activity of Indian borage essential oil against maize weevil. *Geomate Journal*. 2019;16(56):59-64.
 34. Santos FA, Serra CG, Bezerra RJ, Figueredo FG, Matias FF, Menezes IR. Antibacterial activity of *Plectranthus amboinicus* Lour (Lamiaceae) essential oil against *Streptococcus mutans*. *European Journal of Integrative Medicine*. 2016;8(3):293-297.
 35. El-hawary SS, El-sofany RH, Abdel-Monem AR, Ashour RS. Phytochemical screening, DNA fingerprinting, and nutritional value of *Plectranthus amboinicus* (Lour.) Spreng. *Pharmacognosy Journal*. 2012;4(30):10-13.
 36. Shubha JR, Bhatt P. *Plectranthus amboinicus* leaves stimulate growth of probiotic *L. plantarum*: Evidence for ethnobotanical use in diarrhea. *Journal of Ethnopharmacology*. 2015;166:220-227.
 37. Silitonga M, Ilyas S, Hutahaean S, Sipahutar H. Levels of apigenin and immunostimulatory activity of leaf extracts of bangunbangun (*Plectranthus amboinicus* Lour). *International Journal of Biology*. 2015;7(1):46.
 38. Kirtikar KR, Basu BD. *Indian Medicinal Plants*, Lalit Mohan Basu, Allahabad; India. 1935;3:1970-1971.
 39. Chopra RN, Nayar SL, Chopra IC. *The Glossary of Indian Medicinal Plants*, CSIR, New Delhi, 1956, 74-30.
 40. Rai V, Pai VR, Kedilaya P. A preliminary evaluation of anticancer and antioxidant potential of two traditional medicinal plants from Lamiaceae-Pogostemon heyneanus and *Plectranthus amboinicus*. *Journal of Applied Pharmaceutical Science*. 2016;6(8):73-78.
 41. Rout OP, Acharya R, Mishra SK, Sahoo R. Pathorchur (*Coleus aromaticus*): a review of the medicinal evidence for its phytochemistry and pharmacology properties. *International Journal of Applied Biology and Pharmaceutical Technology*. 2012;3(4):348-355.
 42. Chiu YJ, Huang TH, Chiu CS, Lu TC, Chen YW, Peng WH. Analgesic and anti-inflammatory activities of the aqueous extract from *Plectranthus amboinicus* (Lour.) Spreng. both *in vitro* and *in vivo*. Evidence-based complementary and alternative medicine, 2012.
 43. PIER. Pacific Islands Ecosystems at Risk. Honolulu, USA: HEAR, University of Hawaii, 2014. <http://www.hear.org/pier/index.html>
 44. Humbert H. *Flora de Madagascar et des Comores*. Family 175- Labiatae (Flora of Madagascar and the Comoros. Family 175- Labiatae). Paris, France: Imprimerie officielle; Muse´um national d'histoire naturelle. 1951. <http://www.nhbs.com/title/79635/flore-de-madagascar-et-des-comores-fam-175>
 45. Lukhoba CW, Simmonds MS, Paton AJ. *Plectranthus*: A review of ethnobotanical uses. *Journal of ethnopharmacology*. 2006;103(1):1-24.
 46. Prasad N, Basalingappa KM, Gopenath TS, Razvi SM, Murugesan K, Ashok G. Nutritional Significance Of Indian Borage (*Plectranthus amboinicus*): A Review. *Plant Archives*. 2020;20(2):3727-3730
 47. Hussein KT. Effect of some plant extracts in the control of a non-biting Muscoid fly. – Ph.D. Thesis, Fac. Sci. Zag. Univ., Egypt, 1995.
 48. Ahn YJ, Lee SB, Lee HS, Kim GH. Insecticidal and acaricidal activity of carvacrol and thujaplicine derived from *Thujopsis dolabrata* var. hondai sawdust. *Journal of Chemical Ecology*. 1998;24:81-90.
 49. Govindarajan M, Rajeswary M, Hoti SL, Bhattacharyya, A, Benelli G. Eugenol, α -pinene and β -caryophyllene from *Plectranthus barbatus* essential oil as eco-friendly larvicides against malaria, dengue and Japanese encephalitis mosquito vectors. *Parasitology research*. 2016;115(2):807-815.
 50. Andrestian MD, Damanik R, Anwar F, Yuliana ND. Anti-hyperglycemic effect of Torbangun (*Coleus amboinicus* Lour) leaves extract through liver and muscle glycogen deposits in Streptozotocin-induced hyperglycemic Sprague-Dawley rats model. *Medical Laboratory Technology Journal*. 2019;5(2):70-80.
 51. Stearn WT. *Stearns dictionary of plant names for gardeners: A handbook on the origin and meaning of the botanical names of some cultivated plants*. London, UK: Cassell, 1992.
 52. University of Hawaii. Department of Botany Vascular Plant Family Access Page: Lamiaceae (Labiatae). Honolulu, USA: University of Hawaii, 2014. <http://www.botany.hawaii.edu/faculty/carr/lami.htm>
 53. Rajesh PKS, Kumaravelu C, Gopal A, Suganthi S. Studies on identification of medicinal plant variety based on NIR spectroscopy using plant leaves. In 2013 15th International Conference on Advanced Computing Technologies (ICACT) IEEE. 2013 Sept, 1-4.
 54. Staples GW, Kristiansen MS. *Ethnic culinary herbs: A guide to identification and cultivation in Hawaii*. University of Hawaii Press. 1999.
 55. USDA-NRCS. The PLANTS Database. Baton Rouge, USA: National Plant Data Center. 2014. <http://plants.usda.gov/>.
 56. Wagner WL, Lorence DH. *Flora of the Marquesas Islands website*. Washington DC, USA: Smithsonian, Institution, 2014. <http://botany.si.edu/pacificislandbiodiversity/marquesasflora/index.htm>.